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Canadian Science Advisory Secretariat
Newfoundland and Labrador Region | Science Advisory Report 2015/001

STOCK ASSESSMENT OF NAFO SUBDIVISION 3PS COD

Image: Gadus morhua

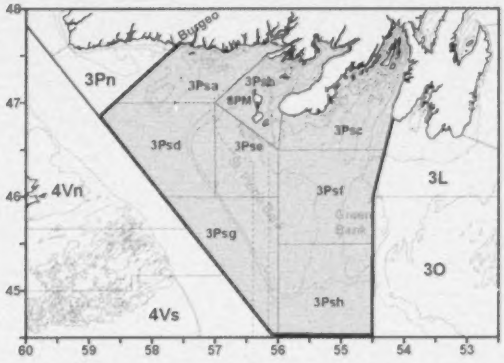

Figure 1: 3Ps management area (shaded) unit areas (solid lines) and economic zone around the French islands of St. Pierre and Miquelon (SPM) (dashed line)

Context:

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank (Figure 1).

The distribution of 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of inshore and offshore sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Cod from this stock generally grow faster than those from areas further northward. Female cod from this stock are generally maturing at younger ages in recent years. For example, about 50% of the females are mature by age 5 (~47 cm) in recent cohorts, compared to only about 10% at age 5 (~55 cm) among cohorts present in the 1970s-early 1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear, and inshore by fixed gear only. Spanish and other non-Canadian fleets heavily exploited the stock in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August 1993 ended in 1997 with a quota set at 10,000 t. Beginning in 2000, the management year was changed to begin on 1 April. The Total Allowable Catch (TAC) for the 2013/14 management year was set at 11,500 t. Under the terms of a 1994 Canada-France agreement, Canada holds 84.4% of the TAC, while the remainder (15.6%) is held by France (St. Pierre et Miquelon).

The present assessment is the result of a request for science advice from the Fisheries Management Branch (NL Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

Participants included Fisheries and Oceans Canada (DFO) scientists, a scientist from IFREMER (France), fisheries managers, academia, fishing industry representatives from Canada and France, and representatives from the province of Newfoundland and Labrador and a non-government organization.

This Science Advisory Report is from the October 14-16, 2014 3Ps Cod Stock Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

January 2015

Canada

SUMMARY

- Reported combined landings by Canada and France have been below the TAC since the 2009/10 season. During the 2013/14 season, less than half (47%) of the 11,500 t TAC was landed.
- Consistent with recent assessments, a cohort model (SURBA) based on the spring DFO survey was used to infer overall stock trends.
- Some of the other sources of information not included in the assessment model (i.e. Sentinel, log book data) show trends that differ from the SURBA results, and these differences are not fully understood. The DFO survey is considered the most appropriate index of stock status because it covers most of the stock area.
- The stock is currently in the cautious zone as defined by the DFO Precautionary Approach (PA) Framework. The spawning stock biomass (SSB) has increased since 2009 and is currently estimated to be 60 percent above the limit reference point (LRP; $B_{Recovery} = SSB_{1994}$). The probability of being below the LRP in 2014 is very low (~0.01).
- Estimated total mortality over 2011-13 averaged 0.53 (41% annual mortality), which is relatively high considering that less than half of the TAC was taken annually over this time period.
- Recruitment has improved over the last decade with most cohorts at or above the time-series (1983-2013) average. In particular, the 2006 cohort is strong, and preliminary indications are that the 2011 and 2012 cohorts are also strong.
- Projection of the stock to 2015 was conducted assuming mortality rates will be within ±20% of current values (2011-13 average). Projected SSB remains stable or increases and remains within the cautious zone.

INTRODUCTION

History of the fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 87,000 t in 1961 (Fig. 2).

After the extension of jurisdiction in 1977, landings increased to peak at almost 59,000 t in 1987 due to increased landings by France. Landings then decreased sharply to a level of about 40,000 t during 1988-91 before decreasing further to 36,000 t in 1992.

A moratorium was imposed in August 1993 after only 15,000 t had been landed. Although offshore landings fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year until the moratorium.

The fishery reopened in May 1997 with a TAC of 10,000 t, and increased to 30,000 t by 1999. In 2000 the management year was changed to begin on 1 April. Total Allowable Catches and landings over the past decade are shown in Table 1 and are described in detail below. The TAC was set at 11,500 t for five consecutive management years (2009/10-2013/14) and was subsequently increased to 13,225 t for the 2014/15 management year.

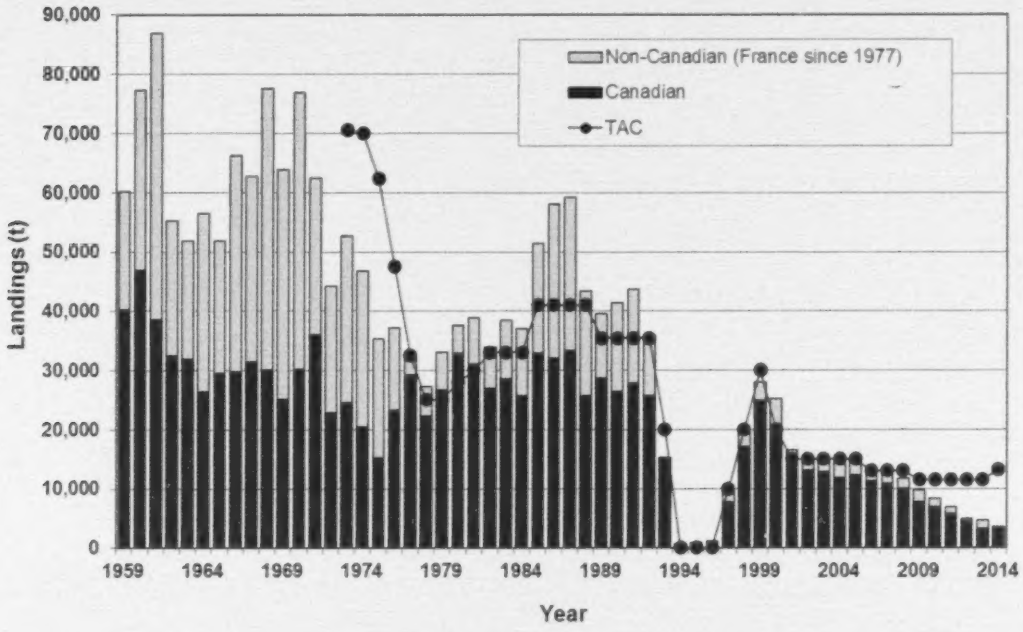

Figure 2. Reported annual landings and TACs (t) from 1959-2014. Values are based on calendar year from 1959-2000 and on management year (1 April-31 March) since then. Landings for 2014 (2014/15 season) are incomplete.

Landings

Table 1: Landings by management year (thousand metric tons).

Management Year	05[3]-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13[1]	13-14[1]	14-15[1,2]
TAC[3]	15.0	13.0	13.0	13.0	11.5	11.5	11.5	11.5	11.5	13.225
Canada	11.7	11.3	10.8[4]	10.6[4]	7.5[4]	6.6[4]	5.2[4]	4.0[4]	4.0[4]	2.4[4]
France	2.2	1.9	2.0	2.0	1.5	1.3	1.1	0.8	1.4	<0.1
Totals	13.9	13.2	12.8	12.6	9.0	7.8	6.3	4.8	5.4	2.4

[1] Provisional.

[2] Approximate landings to 09 October 2014.

[3] TAC is shared between Canada (84.4%) and France (St. Pierre and Miquelon; 15.6%).

[4] Does not include Canadian recreational fisheries.

Reported combined landings by Canada and France have been substantially below the TAC since the 2009/10 season. During the 2013/14 season, less than half (47%) of the 11,500 t TAC was landed. Prior to 2009/10, the TAC had been almost fully subscribed with the exception of the initial four years of TAC regulation. Industry participants have indicated multiple reasons contributing to the recent reduction in landings, including economic factors and reduced availability. Of the 5,428 t landed during

the 2013/14 season, 4,031 t was taken by Canada (including 14 t from sentinel surveys), and 1,397 t was landed by France.

Provisional data (as of 9 October 2014) indicate landings during the ongoing 2014/15 management year were 2,447 t, 75 t of which was landed by France. Although incomplete, these landings to date are relatively low, and suggest that much of the 2014/15 TAC of 13,225 t will likely not be caught.

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. Estimates of recreational fishery landings have not been available since 2006. In assessing stock status, it would be useful to better understand the accuracy of total removals, especially in the post-moratorium period. Given the uncertainty in the reliability of removal estimates during some periods, they are not used in the current analytical assessment.

During the 2013/14 season, approximately two-thirds of the total landings were taken by fixed gears (dominated by gillnet) with the remainder taken by the otter trawl fleet.

Species Biology

Stock structure and **migration patterns** of 3Ps cod are complex. Cod in 3Ps mix with adjacent stocks at the margins of the stock boundary. Some offshore components of the stock migrate seasonally to inshore areas, and there are inshore components that are shoreward of the spring DFO RV trawl survey area. These features add uncertainty to the assessment of stock status. However, since the moratorium, new information has been obtained from various sources, including tagging, acoustic telemetry, and the sentinel fishery. This information has provided a basis for several new measures to be put in place to reduce the potential impact of these factors (i.e., stock structure and migration patterns) on the assessment. Survey timing has been delayed until April (beginning in 1993) and winter area closures have been imposed to reduce the possibility that migrant non-3Ps cod are included in surveys and commercial catches. The area surveyed during the spring DFO RV trawl survey has also been extended shoreward and by 1997 the total area covered increased by 12%. The spring DFO RV trawl survey covers most of the stock so survey trends broadly reflect stock trends.

Maturation in female cod was estimated by cohort. The proportion of female cod maturing at ages 4-6 has increased for all cohorts subsequent to the 1985 cohort. The reasons for the change toward earlier age at maturity are not fully understood but may have a genetic component that is partly a response to high levels of mortality including fishing. Males generally mature about one year younger than females but show a similar trend over time.

Spawning is spatially widespread in 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in the Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. A recent review of spawning time found no indication of any shift in the timing of spawning over the 1997-2009 period.

Growth, calculated from length at age in research trawl survey samples, has varied over time. For cod older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s. For most ages there was an increase in length-at-age from the mid-1990s through the mid-2000s, followed by a period of lower length-at-age in recent years. For many of the ages examined, length-at-age increased in 2014 compared to 2013.

Comparison of post-1992 **condition** with that observed during 1985-92 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. There were signs of improved fish condition during 2008-2013, but both gutted and liver condition have generally remained lower than that observed from the late 1990s to the mid 2000s. The 2014 condition

values were the lowest in the time series. Similarly, estimates of condition from sentinel sampling in recent years are below the time-series average.

ASSESSMENT

Resource Status

Sources of information

A cohort model (SURBA) based on abundance indices from Canadian RV trawl surveys (1972-2014) is used to infer overall stock trends (Cadigan 2010). Additional sources of information are presented (see "Other Data Sources" below), but the current assessment model uses only the RV survey data because it is collected with standardized effort over most of the stock area and is thought to reflect overall trends in the stock.

Research vessel surveys

Canadian DFO RV bottom **trawl surveys** have been conducted in NAFO Subdivision 3Ps since 1972, however, surveys from 1972-82 had poor coverage. The surveyed area was increased by 12% by the addition of strata closer to shore in 1994 and 1997. The DFO RV survey was not completed in 2006.

Survey indices are presented for the expanded DFO survey area (inshore and offshore; denoted "All strata <300 ftm" in Figs. 3 and 4) as well as for the offshore strata ("Offshore <300 ftm" in figures). The DFO RV survey covers most of the stock distribution, and survey trends are considered to broadly reflect stock trends. Any near-shore aggregations in April would not be measured by the DFO RV survey. The majority of the area shoreward of the DFO RV survey lies within inner and western Placentia Bay. There is no recent evidence that a large fraction of the stock is shoreward of the DFO RV survey in April.

The **biomass index** from the offshore strata is variable but exhibits a downward trend from the mid-1980s to the early 1990s (Fig. 3). Values for most of the post-moratorium period up to 2004 were higher than those of the early 1990s, but not as high as those of the 1980s. Biomass estimates in recent years have generally been low, with six of the last eight years being below the 1997-2014 average. Survey catches in 2014 were highest in the Halibut Channel. Survey biomass from the expanded index ("All Strata <300 ftm") shows similar trends to the offshore-only index.

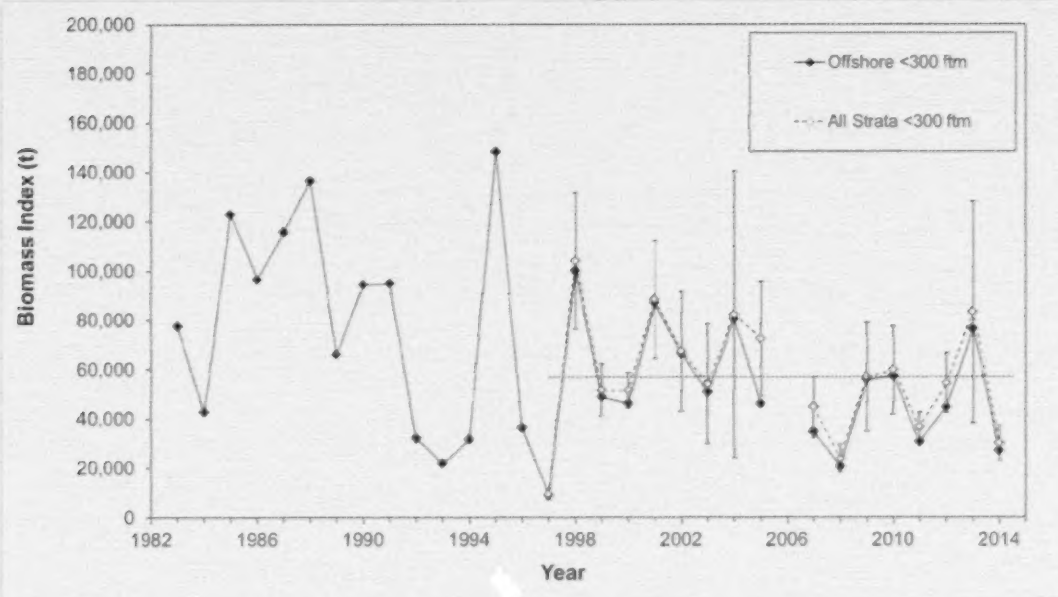

Figure 3. Research vessel survey biomass indices (t) (error bars are 95% confidence intervals for combined survey index–dashed line is the time series average of the combined survey index).

The offshore DFO RV abundance index is variable, but values during the 1990s were generally lower than those from the 1980s (Fig. 4). Abundance was low during the 2000s but has increased somewhat in recent years with five of the last six years being at or above average. In particular the 2013 estimate was very high but characterized by a high degree of uncertainty.

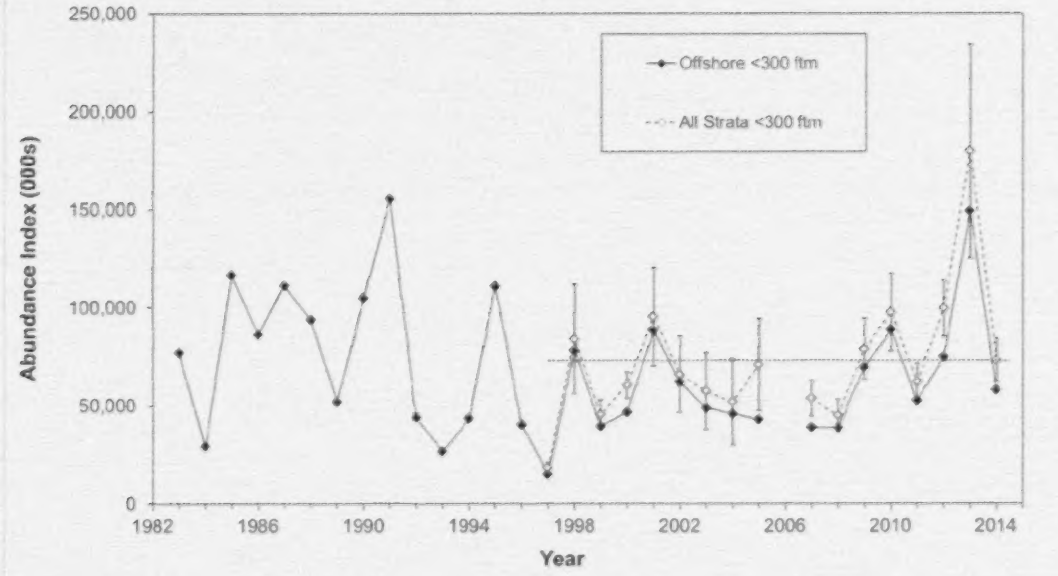

Figure 4. Research vessel survey abundance indices (error bars are 95% confidence intervals for combined survey – dashed line is average of combined survey index).

Age Composition

Catches during the 2014 RV survey consisted mainly of cod aged 2-4 (76% of abundance index). Early indications are that the 2011 (age 3 in 2014) and 2012 (age 2 in 2014) year classes are strong and are widely distributed throughout the survey area. The degree to which these two year-classes will contribute to future fisheries is as yet uncertain.

Cohort Analysis Reference Points

The LRP for this stock is $B_{Recovery}$, the lowest observed SSB from which there has been a sustained recovery. The 1994 value of SSB has been identified as the LRP. The Upper Stock Reference (USR) has recently been defined as two times the LRP (see Management Considerations section). Removal reference points have not been identified for this stock.

Spawning Biomass

Cohort analyses of the RV data indicated that SSB declined by 60% over 2004-09 (Fig. 5). Median SSB was estimated to be below the LRP in 2008 and 2009. SSB increased considerably over 2009-2012 and has since been relatively stable. The 2014 estimate is approximately 1.6 times higher than the LRP. The probability of being below the LRP in 2014 is very low (~0.01). As a result of improved recruitment and recent increases in the proportion mature-at-age, 81% of the 2014 SSB is comprised of fish of ages 5-8.

In the previous assessment the SSB demonstrated a steadily increasing trend from 2009-2013 with the 2013 estimate being twice the level of the LRP. In the current assessment, however, SSB levels off after 2012, with the 2013 estimate being 1.6 times the level of the LRP. Retrospective revisions are not uncommon in cohort models which use annual information to predict the abundance of multiple cohorts. The relatively large revision to the SSB estimates is owing to the fact that 2014 survey estimates have decreased considerably from the large (and unexpected) values of the 2013 survey. Several recent year-classes were revised downwards, with the greatest revision to the 2011 year-class. In addition, changes in average mortality and the estimated proportions mature at age have also contributed to the revision in SSB.

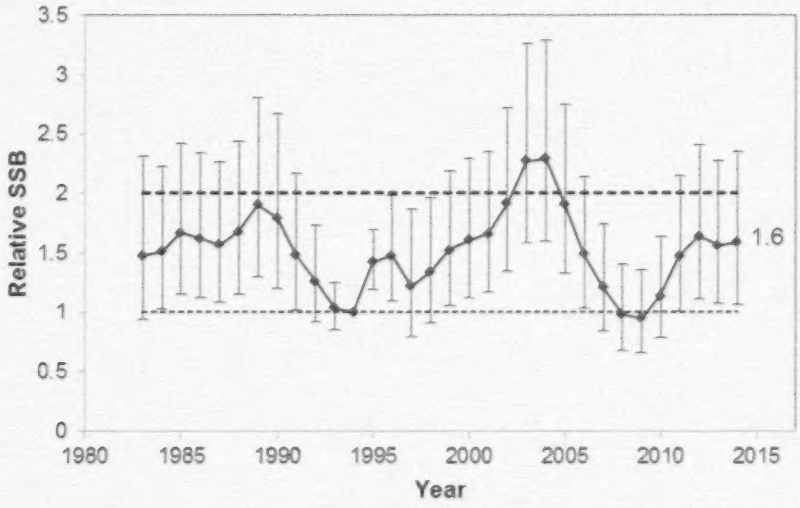

Figure 5. Cohort analysis estimates of SSB, relative to the 1994 value (median estimate with 95% confidence interval). A thin horizontal dashed line at one (reference level) represents the SSB Limit Reference Point and a thick horizontal dashed line at two represents the Upper Stock Reference (i.e. 2 x LRP). Text label indicates the current SSB relative to the LRP.

Mortality Rates

Total mortality rates reflect mortality due to all causes, including fishing. Estimated total mortality from a cohort model (Fig. 6) for ages 5-10 declined from 2006-2011 but has increased again in the last two years, with an average 2011-13 value of 0.53 (41% annual mortality). This value is weighted by population number at each of ages 5-10. Current mortality estimates are well above the time-series average. This is of particular concern given that less than half of the TAC has been taken annually over the last three years. It remains unclear whether or not these mortality rates are sustainable over the longer term.

This analysis assumes that age 4 and older fish are equally selected (flat-topped) by the RV survey. Alternate assumptions for the relative catchability (domed) of cod ages 4+ were explored in a previous assessment and gave similar trends (see DFO, 2009). Flat-topped selectivity is commonly assumed unless there is evidence otherwise.

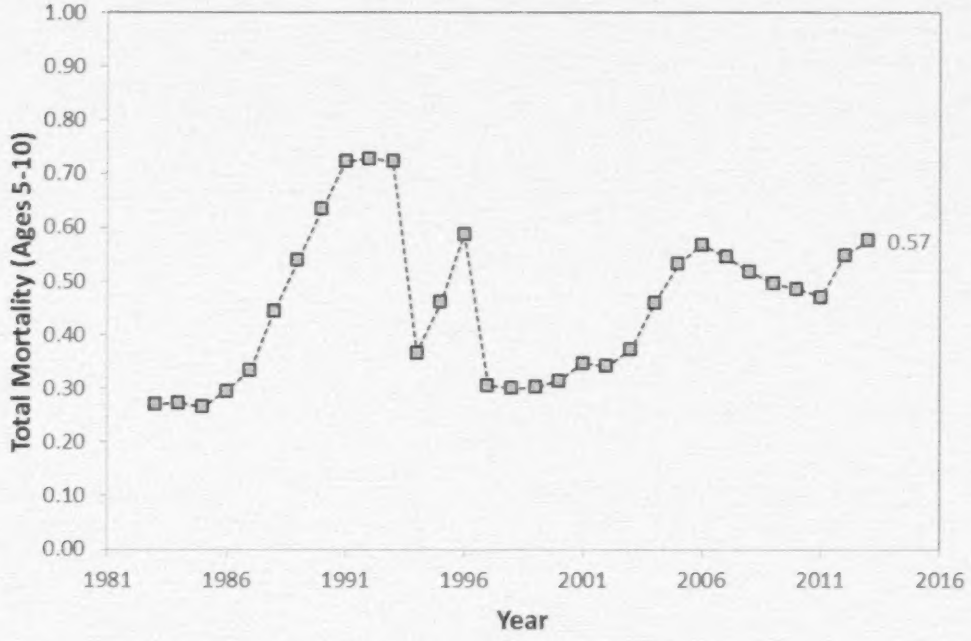

Figure 6. Cohort analysis estimates of population weighted average annual mortality (ages 5-10). Text label indicates the estimated total mortality for 2013.

Recruitment

Recruitment (Fig. 7) has improved over the last decade with most cohorts at or above the time series (1983-2013) average. In particular, the 2006 cohort is estimated to be quite strong. Preliminary indications are that the 2011 and 2012 cohorts are among the strongest in the time-series. However, it should be noted that the uncertainty around the estimates for these recent cohorts is quite high and the estimates may be revised as additional data are collected.

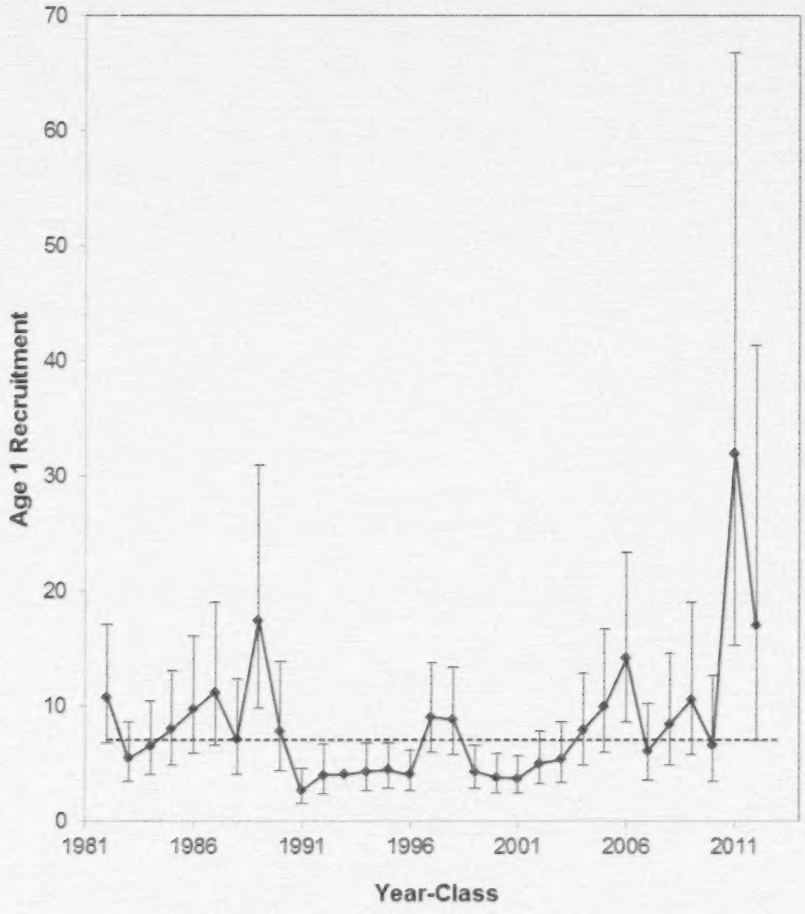

Figure 7. Estimated relative year-class strength from cohort model (median estimate with 95% confidence intervals). The dashed horizontal line is the time-series median.

Projection

Projection of the stock to 2015 was conducted assuming mortality rates will be within ±20% of current values (2011-13 average). Projection scenarios indicate that the 2015 SSB will remain stable or increase from the 2014 estimate. In each of the scenarios, the probability of being below the LRP in 2015 is very low (<0.01). In recent assessments, three year projections were provided to advise management decisions. In this assessment, projection estimates of SSB for subsequent years are currently considered unreliable given the heavy influence of the uncertain and exceptionally large 2011 and 2012 year classes. These two year classes are currently estimated to be very strong and by 2015, when very few of these fish would be mature at ages 3 and 4, they would constitute 20% of the projected SSB. As they mature in subsequent years, these year classes will dominate the projected SSB. Therefore, more reliable estimates of the 2011 and 2012 year classes are required to project the stock beyond 2015.

Other data sources

Other sources of information were considered in the assessment to provide perspectives on stock status in addition to the DFO survey indices. These sources of information include data from the Sentinel survey (1995-2013), science logbooks for vessels less than 35 feet (1997-2013) and logbooks for vessels greater than 35 feet (1998-2013). Results of a telephone survey of inshore Canadian fish harvesters and exploitation (harvest) rates estimated from tagging experiments in Placentia Bay (and more recently Fortune Bay) were also available. Any differences in trends between these other data sources and the DFO survey are difficult to reconcile but attributed to seasonal changes in stock distribution, differing selectivity of various gear types, or the degree to which the various data sources track only certain subareas/ components versus the entire distribution of the stock.

Sentinel survey

Fixed gear sentinel surveys have been conducted at sites along the south coast of Newfoundland from St. Bride's to Burgeo from 1995 through 2014. Gillnet results come mostly from sites in Placentia Bay whereas line-trawl results come mostly from sites west of the Burin Peninsula. The sentinel survey for 2014 is still ongoing; hence, the data for 2014 are incomplete and were not included in the modeling reported below.

The sentinel survey data were standardized to remove site and seasonal effects to produce annual indices of the total and age-specific catch rates (Fig. 8).

The standardized total annual catch rate for gillnets was highest from 1995-97, but progressively lower in 1998 and 1999, and remained quite low from 2000 to 2013 (Fig. 8, upper panel). The line-trawl catch rates were high in 1995 with a steady decline to 1999, but were subsequently fairly constant through 2009 (Fig. 8, lower panel). Most recent values are among the lowest in the time-series. Although considerable declines have been estimated by both gear types, the magnitude of this decline is inconsistent across gear types.

The standardized age-specific catch rates for sentinel gillnets and line-trawls show similar trends with the relatively strong 1989 and 1990 year-classes being replaced by subsequent weaker year-classes resulting in an overall decline in catch rates. Although the magnitude of the sentinel catch rates has been generally constant for more than a decade, the 1997 and 1998 year-classes were consistently evident in both age disaggregated sentinel indices. In addition, the 2004 year-class appears to be well-represented only within line-trawl results. The relative strength of more recent year-classes in the sentinel results is less clear, but generally indicates that they are relatively weak. Comparison of sentinel catch rates and the RV index at times show inconsistent age compositions; these differences are not fully understood. As an example, the 2006 year-class ranks above average in the RV survey, but does not appear particularly strong in either sentinel index even though fish in this year-class are now available to these gears. The 2011 and 2012 year classes, which appear strong in the survey, are not yet fully selected by either of the Sentinel gears.

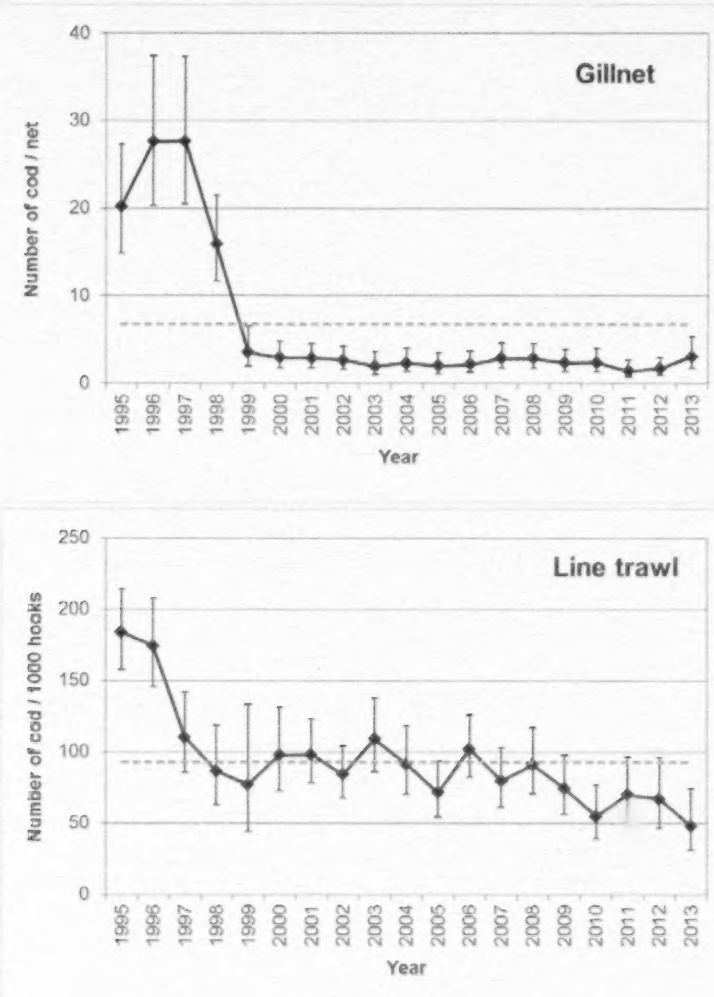

Figure 8. Standardized sentinel catch rates for gillnets (upper panel) and line-trawls (lower panel). Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Logbooks

There is considerable uncertainty in the interpretation of fishery catch rate data. These data may be more reflective of changes in fishery performance or the nature of the fishery than changes in population size.

Logbooks for <35' Vessels

Standardized annual catch rates from science logbooks (<35' sector) for Canadian vessels fishing gillnets show a declining trend over 1998-2000, but have subsequently been fairly constant (Fig. 9, upper panel) and below the time series average. Line-trawl catch rates show a much different pattern with a greater degree of variation (Fig. 9, lower panel). After peaking in 2006, line-trawl catch rates generally declined and in 2013 were near the time-series average. The commercial catch rate index is based on weight of fish caught whereas the sentinel index is based on numbers. As with the sentinel results, there is contrast between the two gear-types in current catch rates relative to the time-series

average. For gillnets, current CPUE is 12% below average, whereas current line-trawl CPUE is 2% above average.

The percentage of the catch from the <35' sector that is accounted for in the standardized logbook indices has declined over time and now represents less than 35% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality, and comparability, of this index over time, such that it is unclear if the CPUE trends reflect the fishery as a whole.

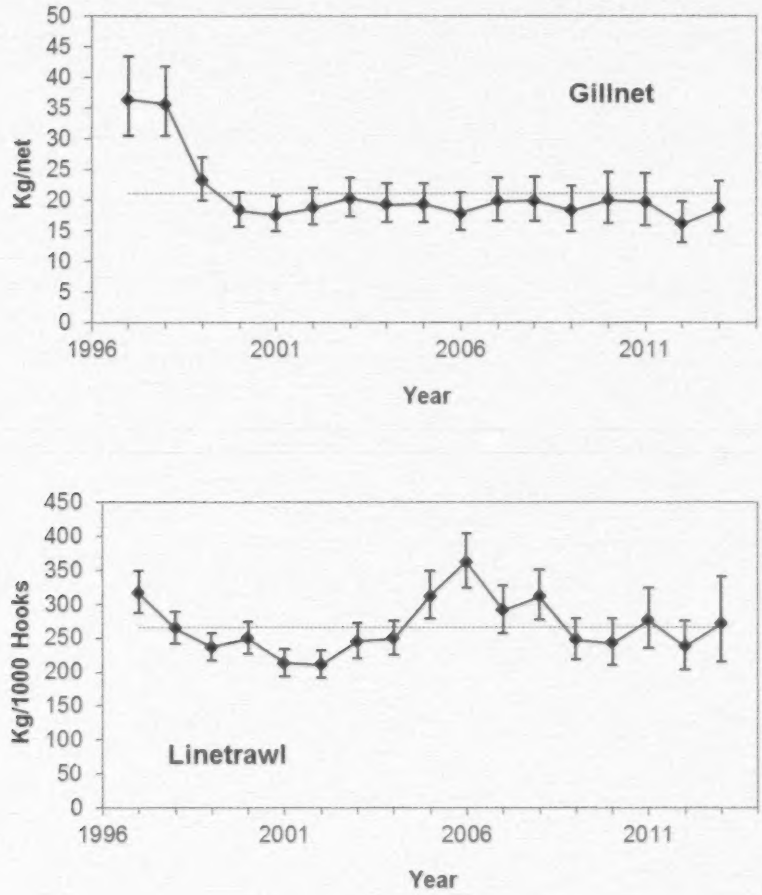

Figure 9. Standardized catch rates for gillnets and line-trawls from science logbooks for vessels <35'. Error bars are 95% confidence intervals; dashed line is the time-series average.

Logbooks for >35' Vessels

The spatial distributions of both landings and unstandardized catch rates over 1998 to 2013 were determined using logbook data from the greater than 35 foot fleet. Data on landings and catch rates for otter trawls, gillnets and linetrawls were analyzed. For all three gears, there was substantial spatial concentration in landings and a reduction in the number of areas reporting high landings over the time-series. From 1998 to 2010, catch rates in otter trawls were consistently high in the Halibut Channel and they were also high in areas of St. Pierre Bank during most years. Otter trawl catch rates declined in

the Halibut Channel from 2010 to 2012. During 2013, limited effort was reported by otter trawlers in the Halibut Channel and only moderate catch rates were reported on St. Pierre Bank. Catch rates in gillnets were highest in Placentia Bay and on St. Pierre Bank from 1998 to 2007, but since 2007 the highest catch rates were typically reported only on the bank. Spatial trends differed between gillnets and linetrawls. The number of locations reporting high catch rates by linetrawls generally increased from 1998 to 2010, but subsequently declined to one location in Placentia Bay during 2013.

Tagging

The geographical coverage of tagging since 2007 has been limited to inshore areas, which causes some uncertainty as to how results relate to the stock as a whole. The number of cod and areas where tagging was conducted was expanded from only 3Psc (Placentia Bay) to include 3Psb (Fortune Bay) in 2012. Although exploitation rates based on tagging of cod in these inshore areas may not be applicable to other areas, or to the stock as a whole, these inshore regions account for a significant portion (~ 50%) of the overall annual landings from the stock.

Exploitation rates for 2013 and updated estimates for 2012 were obtained. These incorporated annual estimates of tag reporting rates (~72% during 2012-2013) based on high-reward tagging. Estimated harvest rates based on various size groups of cod tagged and released inshore have been broadly similar over 2011-13. In 2012, the estimated harvest rate for cod >55 cm released in Placentia Bay was 19%. In 2013, the harvest rates were slightly lower (13%) and similar for cod tagged in Placentia Bay or Fortune Bay. The distribution of tag returns did not give any indication of significant exploitation of 3Ps cod in neighbouring stock areas (3KL/3Pn-4R), although local movement of cod between 3Pn and western 3Psa was evident.

Sources of Uncertainty

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. Estimates of recreational fishery landings have not been available since 2006. In assessing stock status, it would be useful to better understand the accuracy of total removals, especially in the post-moratorium period. Given these uncertainties and the variability in the reliability of removals estimates, they are not used in the current analytical assessment. Assessment models do exist that are capable of handling uncertainty in the catch estimates but some information would still be needed in order to place reasonable bounds on the landings.

Comparison of sentinel catch rates and the RV index at times show inconsistent age-compositions. The differences in cohort strength between stock components could be due to changing stock distribution within the year, gear selectivity, or the spatial coverage of each index. As an example, the sentinel gillnet data consistently measured the 1992 cohort as being an above average fraction of the annual catch. This cohort was also important to the commercial gillnet catch, but was not notable in the RV index. A similar phenomenon exists for the 2004 cohort (detected by sentinel line-trawl but not sentinel gillnet or RV index).

There is uncertainty regarding the origins of fish found in 3Ps at various times of the year. Tagging and telemetry experiments show that there is mixing with adjacent stocks (southern 3L and 3Pn4RS) and this may vary over time. However, results indicate that exploitation of fish tagged within Placentia Bay has been predominantly within that area, even after several years at liberty.

The geographical coverage of tagging since 2007 is limited to inshore areas; during 2008-11 cod were only tagged in Placentia Bay, and in 2012 and 2013 in Placentia Bay and Fortune Bay. The lack of recent tagging in other areas adds uncertainty to our understanding of natural mortality rates,

exploitation rates, stock structure, as well as movement patterns and how these influence survey and commercial catch rates in the recent period.

The relative efficiency of the survey trawl at capturing different age groups is uncertain. Differing patterns of catchability were explored in a recent assessment and yielded a similar outcome in terms of current status relative to the LRP. If the catchabilities differ from the assumed values, stock dynamics may differ from the results presented above.

Survey indices are at times influenced by "year-effects", an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation, etc.) which may be unrelated to absolute stock size. There are strong indications that the 2013 survey may have been influenced by a year effect. In 2013, a large single catch of fish on Burgeo Bank resulted in >50% of the overall biomass being located in this particular area and causing a large spike in the survey indices for that year. This is unusual and is not consistent with survey catches in this area in either 2012 or 2014. In addition, in the 2013 RV survey, the estimated abundance of multiple cohorts increased compared to observations of these same cohorts at one age younger in 2012. For at least some cohorts, this change is largely influenced by the single large survey catch described above. The number of fish in a cohort cannot increase as it ages (without immigration) and when analyses suggest that such an increase has occurred it is considered evidence for a year effect. In the 2013 survey, the 2011 year class (age 2 fish) was estimated to be by far the strongest in the times series. Subsequently, the current estimated strength for this year class has been downgraded but still appears relatively strong.

The percentage of the catch from the <35' sector that is recorded within the logbook database has declined over time and now represents only about 35% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality and comparability of the standardized catch rate index derived from these data over the time series.

Age at 50% maturity has been declining in recent years. The proportion of female cod maturing at younger ages has increased for all cohorts subsequent to the 1986 cohort, resulting in an increased proportion of young fish contributing to the SSB. It is uncertain whether or not these small, young fish are effective spawners.

CONCLUSIONS AND ADVICE

- Reported combined landings by Canada and France have been below the TAC since the 2009/10 season. During the 2013/14 season, less than half (47%) of the 11,500 t TAC was landed.
- Consistent with recent assessments, a cohort model (SURBA) based on the spring DFO survey was used to infer overall stock trends.
- Some of the other sources of information not included in the assessment model (i.e. Sentinel, log book data) show trends that differ from the SURBA results, and these differences are not fully understood. The DFO survey is considered the most appropriate index of stock status because it covers most of the stock area.
- The stock is currently in the cautious zone as defined by the DFO Precautionary Approach (PA) Framework. SSB has increased since 2009 and is currently estimated to be 60 percent above the limit reference point (LRP; $B_{Recovery} = SSB_{1994}$). The probability of being below the LRP in 2014 is very low (~0.01).
- Estimated total mortality over 2011-13 averaged 0.53 (41% annual mortality), which is relatively high considering that less than half of the TAC was taken annually over this time period.
- Recruitment has improved over the last decade with most cohorts at or above the time-series (1983-2013) average. In particular, the 2006 cohort is strong, and preliminary indications are that the 2011 and 2012 cohorts are also strong.

- Projection of the stock to 2015 was conducted assuming mortality rates will be within ±20% of current values (2011-13 average). Projected SSB remains stable or increases and remains within the cautious zone.

OTHER CONSIDERATIONS

Management Considerations

The Conservation Plan and Rebuilding Strategy (CPRS) received Ministerial approval during the late stages of the current assessment meeting and will now guide Canada's management position on this co-managed stock. Based on the CPRS, TAC advice for 2015/16 would be 13,495 t, a 2% increase over the previous year. An initial evaluation of the CPRS found it to be PA compliant and to lead to a sustainable fishery over the long-term (but with yield lower than historical catch levels of 40-60kt). Further work is planned to continue this evaluation. Discussion is needed between DFO Science and Fisheries Management to determine how future Terms of Reference and requests for advice should be structured in order to correspond to the newly approved CPRS.

The level of total removals is uncertain but less so in the post-moratorium period. In assessing stock status, it would be useful to better understand the accuracy of total removals. Accurate estimates of recreational fishery landings are also required.

Estimation of maximum sustainable yield (MSY)-based reference points (FMSY and BMSY) will require an assessment framework review including further peer review of the modeling approach used to quantify these reference points.

Management should recognize that cod which overwinter in 3Ps are also exploited in adjacent stock areas (Division 3L and Subdivision 3Pn). Hence management actions in these stock areas should consider potential impacts on 3Ps cod. Consequences of area/time closures should be carefully considered as these may result in higher exploitation rates on the components of the stock that remain open to fishing. The fishery should be managed such that catches are not concentrated in ways that result in high exploitation rates on any stock components.

Management should be aware of within-year variations in the individual weight of cod. Greatest individual yield can be gained when fish are in peak condition, typically in late fall/early winter, while minimizing the total number of individuals removed from the stock.

When average fish size (age) in commercial catches is reduced through either depletion of older cohorts or recruitment of younger cohorts, the numbers of fish removed per ton of landed catch is increased.

A seasonal closure of the entire 3Ps stock area (typically March 1 – mid May) occurs annually and is intended to prevent fishing during the cod spawning season. Spawning closures of various forms have been used for numerous cod stocks throughout the North Atlantic but the efficacy of such closures is difficult to evaluate due to potentially confounding effects of other simultaneously implemented management measures and a general lack of clear objectives. Closures that span too narrow a time period or geographic area can be ineffective because spawning fish are not entirely protected and/or displacement of effort to other times/areas can result in no overall reduction in fishing mortality. The 3Ps spawning closure covers the entire stock area and so spatial coverage is not a concern. However, the current timing of cod spawning in 3Ps is not well understood and cannot be fully ascertained via the DFO RV survey due to its short temporal coverage of the area each year. Therefore, the timing of the closure relative to the timing of spawning cannot be evaluated.

Temperature and Physical Oceanography

Oceanographic information collected during the spring DFO RV surveys indicated that near- bottom temperatures throughout NAFO subdivision 3Ps have been warming during the past decade reaching two standard deviations above normal in 2011 and 2012 before decreasing to one standard deviation above normal in 2013 and 2014. A further decrease to near-normal values was observed in waters depths <100 m on St. Pierre Bank in 2014. Survey catches of cod are generally lower in years where relatively large incursions of cold/fresh water from the eastern NL shelf dominate, indicating an apparent effect on cod distributions and their availability to the RV surveys. Furthermore, significant positive correlations were found between survey abundance and both bottom temperature and the area of the bottom habitat covered by water with temperatures greater than 2°C. The areal extent of bottom water with temperatures >2°C has remained relatively constant at about 50% of the total 3Ps area, although actual temperature measurements show considerable inter-annual variability. The current conditions are comparable to those of the late 1970s and early 1980s when the stock was more productive and indeed some of the recent improvements in recruitment have coincided with the warming temperature trend.

Ecosystem Considerations

Considering the broader ecosystem-wide perspective, the fish community in 3Ps declined during the mid-1980s, and early-1990s; this decline was also accompanied by a decrease in average fish size. Since the mid-1990s, the overall biomass and abundance of the fish community has increased. The overall biomass increase has been moderate, but the increase in abundance has been clear, being led by planktivorous (plankton-eating) fishes.

Atlantic cod is an important and dominant species among piscivorous (fish-eating) fishes in 3Ps. In the late 2000s and early 2010s, although cod remains an important component in this fish functional group, its dominance level has lessened, and other species (mostly silver hake (*Merluccius bilinearis*), but also pollock (*Pollachius virens*) in some years) have become more prominent in the overall piscivorous fish biomass. These are "warmer-water" species, and their increases may be linked to the warming trend in this ecosystem. In 2014, and for the first time, silver hake replaced Atlantic cod as the dominant species in this functional group.

In addition to the changes within fish functional groups, the trends of some functional groups also show correlated patterns of increases and decreases between 1996 and 2014. There is an inverse relationship between the small and medium benthivore (bottom feeders) biomass, while shellfish (shrimps and snow crab) and small benthivores show similar patterns.

The limited data available for cod diet in 3Ps suggests a highly variable diet, with different prey groups being important over the years. Redfish was important in 1993-1995, with forage fishes (capelin and sandlance) appearing in 1996 and capelin becoming dominant in 1997. In 2013-2014 cod diet has been dominated by sandlance and snow crab for small and large cod respectively. The diet of other predators in the region (American plaice, turbot, and yellowtail flounder) confirm the increased availability of sandlance in 2014 relative to 2013, while snow crab was only an important prey item for cod. Spring diet comparisons between Atlantic cod, silver hake, pollock, and haddock on the shelf edge and slopes of the banks (areas of high spatial overlap) suggest low diet similarity among these predators, and no evidence of predation by these species on Atlantic cod.

The observed warming of this system, together with recent increases of "warmer-water" species like sandlance, and silver hake, and the correlated trends in medium and small benthivores suggests that the structure of this ecosystem is changing. Until the extent and magnitude of these changes, as they relate to cod, can be fully evaluated, system-wide management with higher than normal risk aversion would be advisable.

Stakeholder Perspectives

Fish Harvesters attending the assessment meeting noted that cod condition appears to be good. While still at a low level, capelin was more abundant in inshore areas around Placentia Bay during 2014 than they have been for a number of years. The abundance of grey seals in Fortune Bay and areas to the west appears to be high and fish harvesters are concerned about the potential for increased mortality on cod. Fish harvesters noted that while there has been no significant change in their commercial catch rates during the last 5 years, there have been wide annual variations in abundance estimates from the 3Ps spring DFO survey and this is cause for concern.

Canadian fixed-gear fish harvesters' perspectives on the 2013 fishery were compiled based on the results of the telephone survey conducted by the FFAW in September 2014. Most fish harvesters reported that the 2013 abundance was similar to 2012 abundance. These year over year comparisons have remained relatively stable since 2005. However, there was considerably more variability in responses when fish harvesters were asked to rate their 2013 catch rates against all years fishing. Twenty-five percent of fish harvesters from Area 11 rated 2013 catch rates as the worst and 5% as the best catch rates in their experience. Responses from Area 10 and St. Pierre Bank were less variable reporting average or better than average catch rates in 2013. Most fish harvesters reported condition or health of cod was good in 2013. Fish harvesters reported that baitfish were at a low level and declining, except on St. Pierre Bank.

In 2013, the Saint-Pierre et Miquelon industrial fleet fished almost its entire quota. The Saint-Pierre et Miquelon artisanal fleet fished less than half of its quota. Harvesting only really started in November, when the Newfoundland plants started accepting cod. By that time, the weather was too bad for most of the artisanal fleet to work, so the results of the artisanal fleet are the sum of the work of only a few ships. There were no concerns about the abundance of fish or the catch rates and cod appeared to be in good condition.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 14-16, 2014 3Ps Cod Stock Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Cadigan, N.G. 2010. Trends in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Cod (*Gadus morhua*) stock size based on a separable total mortality model and the Fisheries and Oceans Canada Research Vessel survey index. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/015.

DFO, 2009. Stock Assessment of Subdivision 3Ps cod. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/063.

THIS REPORT IS AVAILABLE FROM THE:

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ISSN 1919-5087
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Correct Citation for this Publication:

DFO. 2015. Stock Assessment of NAFO subdivision 3Ps cod. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/001.

Aussi disponible en français :

MPO. 2015. Évaluation du stock de morue dans la sous-division 3Ps de l'OPANO. Secr. can. de consult. sci. du MPO, Avis sci. 2015/001.